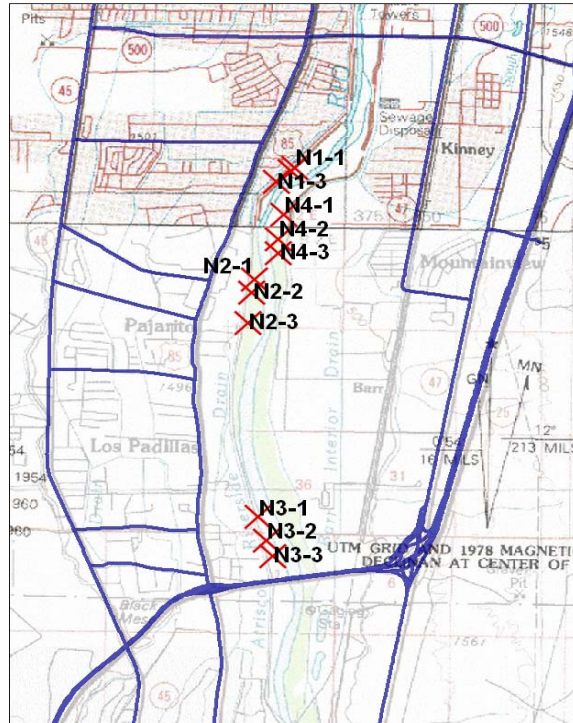


Response of Groundwater Levels and Temperatures to Mechanical Removal of Invasive Plants

Rocky Mountain Research Station Middle Rio Grande Fuels Reduction Study Progress through December 2005



**2005 Progress Report Presented to Rocky Mountain Research Station,
Albuquerque, New Mexico
March 2006
University of New Mexico
Water Resources Program (WRP)
Joint Venture Agreement with USDA Forest Service**

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Introduction

The following provides a summary of progress through December 2005 on the hydrological portion of the Middle Rio Grande Fuels Reduction Project (FRS). The primary goals of the study are to: 1) validate and prepare data for further analysis by merging the data files into Microsoft Excel compatible Comma Separated Value (CSV), one file per well, to facilitate data sharing amongst researchers, 2) characterize the response of groundwater levels and temperatures to the three types of treatments performed at each site, and 3) link the dataset to regional spatial data such as soil maps and to time-series data such as river discharge, precipitation, surface temperature, and humidity.

Tasks completed to date that address the above goals include: 1) collection of groundwater data from data loggers, 2) maintenance of wells and data loggers, 3) creation of an ArcGIS document containing well locations and topographical area maps for future integration of spatial data, 4) merging of all North site data files into time-stamped Microsoft Excel compatible Comma Separated Value (CSV) files, one file per well, 5) preliminary validation and analysis of the North Block, Site 1, Well C (N1C) control site data, and 6) preliminary visualization of regional precipitation and river discharge records.

Overview of Project Data

Pre-existing Site Tables, including:

- Coordinates of wells
- Timelines of sampling, treatment progress, and other events effecting sites along with actions taken
- Ecological site descriptions performed by Forest Service staff, including soil profile and topology surveys

Logger Data Files, including:

- Logger descriptions
- Distance from well Top of Casing (TOC) to data logger
- Groundwater levels and temperatures at 15-minute sample intervals
- All times in UTC+6
- Groundwater levels above sensor and/or from top of well-casings (to be validated)
- Conversion to time-stamped Microsoft Excel-compatible Comma Separated Value (CSV) files
- CSV file merging and labeling, one file per well

Regional Data:

- ArcGIS base map created using Regional Geographic Information System (RGIS) data (see http://rgis.unm.edu/data_entry.cfm)
 - Locations of each well added to base map
 - RGIS topographic and regional road map layers added to base map

- Regional precipitation and temperature monthly averages obtained from the Desert Research Institute's Western Regional Climate Center (see <http://www.wrcc.dri.edu/summary/climsmnm.html>)
- Rio Grande discharge monthly averages obtained from the United States Geological Survey (see <http://waterdata.usgs.gov/nwis>)
- Soil data obtained from the Natural Resource Conservation Service (NRCS) (see <http://soildatamart.nrcs.usda.gov/>)

Methods

Three uniform blocks (North, Middle, and South) were selected to serve as replicates for proposed treatments (see Table 1). Within each block, four sites were selected to be treated and monitored. A randomized block design was created to assign the three treatments plus a control to each of the four sites within each block.

Table 1. Summary of Treatment Sites.

Block	Site	Area (ha)	Groundwater Sampling Started	Treatment Type	Dates of Treatments Performed	Treatments Completed as of 2005
NORTH	North 1	16.07	5/1/2000	Control Site	Control Site	None-Control site
NORTH	North 2	18.33	5/1/2000	Re-vegetation with Native Vegetation	2002-Nov./2003-Nov.	Cut, Chip, Herbicide
NORTH	North 3	17.03	5/1/2000	Mechanical Removal and Chipping	2003-Apr./2004-Apr.	Cut, Chip, Herbicide, Firewood
NORTH	North 4	23.43	5/1/2000	Controlled Burn	2002-Nov./2003-Apr.	Cut, Pile, Herbicide, Firewood
MIDDLE	Middle 1	19.41	5/1/2000	Mechanical Removal and Chipping	2002-Nov./2004-Mar.	Cut, Chip, Herbicide, Firewood
MIDDLE	Middle 2	29.17	5/1/2000	Controlled Burn	2004-Oct./2004-Dec.	Cut, Chip, Herbicide, Firewood
MIDDLE	Middle 3	13.21	5/1/2000	Re-vegetation with Native Vegetation	2004-Apr.	Cut, Chip, Herbicide, Firewood
MIDDLE	Middle 7	35.00	5/1/2000	Control Site	Control Site	None-Control site
SOUTH	South 1	28.87	5/1/2000	Control Site	Control Site	None-Control site
SOUTH	South 2	15.54	5/1/2000	Re-vegetation with Native Vegetation	2003-Feb./2003-Apr.	Cut, Pile, Herbicide, Firewood
SOUTH	South 3	26.71	5/1/2000	Controlled Burn	2002-Nov./2003-Feb.	Cut, Pile, Firewood, Herbicide
SOUTH	South 4	15.45	5/1/2000	Mechanical Removal and Chipping	2002-Nov./2003-Feb.	Cut, Chip, Herbicide, Firewood
						Updated: March 2006

Two groundwater observation wells were installed at each of the 12 study sites two years prior to treatment. Each well consists of a two inch diameter, five foot long, perforated stainless-steel well point driven into the saturated zone. Each well extends three feet above the soil surface via a two inch diameter galvanized pipe that is fitted with a locking cap.

Each well was fitted with an In-Situ MiniTroll data logger to monitor changes in groundwater before, during, and after treatments. Loggers measure the groundwater level at every site via an internal pressure transducer and measure the temperature at one of two wells at each site. Measurements are taken every 15 minutes.

Data are collected regularly from loggers using a handheld computer. The data files are downloaded to a PC and converted in bulk to time-stamped CSV files using In-Situ's AutoCSV utility (see http://www.in-situ.com/In-Situ/Downloads/Downloads_Software.html). Preliminary inspection was conducted using Microsoft Excel. CSV preprocessing was conducted using sed (see <http://www.gnu.org/software/sed/>) and vim (see <http://www.vim.org/>). Further processing of the CSV files, including merging, validation, and visualization, was conducted using the R open source statistical analysis package (see <http://www.r-project.org/>). All data were processed using a reference time zone of UTC+6. Future consideration will be given to accurately aligning time series with respect to time zone.

Existing site tables of well coordinates were first converted into the ArcGIS-compatible DBF format using Microsoft Excel. The resulting files were then imported into an ArcGIS base map of New Mexico obtained from RGIS. Topographical area maps were obtained and imported in the MrSid format.

Progress

As of now, removal treatments have been completed in their proposed sites. Monitoring well data collection is still ongoing to determine the effects of these treatments on selected ecosystem parameters. Currently, data from the North sites have been collected up to December 2005 and the Middle and South sites have data up to August 2005.

All data files from the North site have been merged into one time-stamped CSV file per well. Preliminary inspection reveals several gaps in the record, in addition to numerous outliers. Well C of the North Control Site (N1C) proved to be a high-quality record and is visualized here as an example (see Figure 1). Date ranges and summary statistics for the N1C record are also included (see Table 2).

Table 2. Analysis of North 1 Control C Groundwater.

Record Begins:	6/21/2001 13:58	
Record Ends:	2/25/2006 13:44	
	Temperature, C	Depth above Logger (cm)
Minimum	10.40	40.99
1st Quarter	12.76	54.85
Median	15.79	60.33
Mean	15.20	63.48
3rd Quarter	17.28	67.06
Maximum	19.15	159.34
Total Samples	158660.00	158660.00
Standard Deviation	2.57	15.62

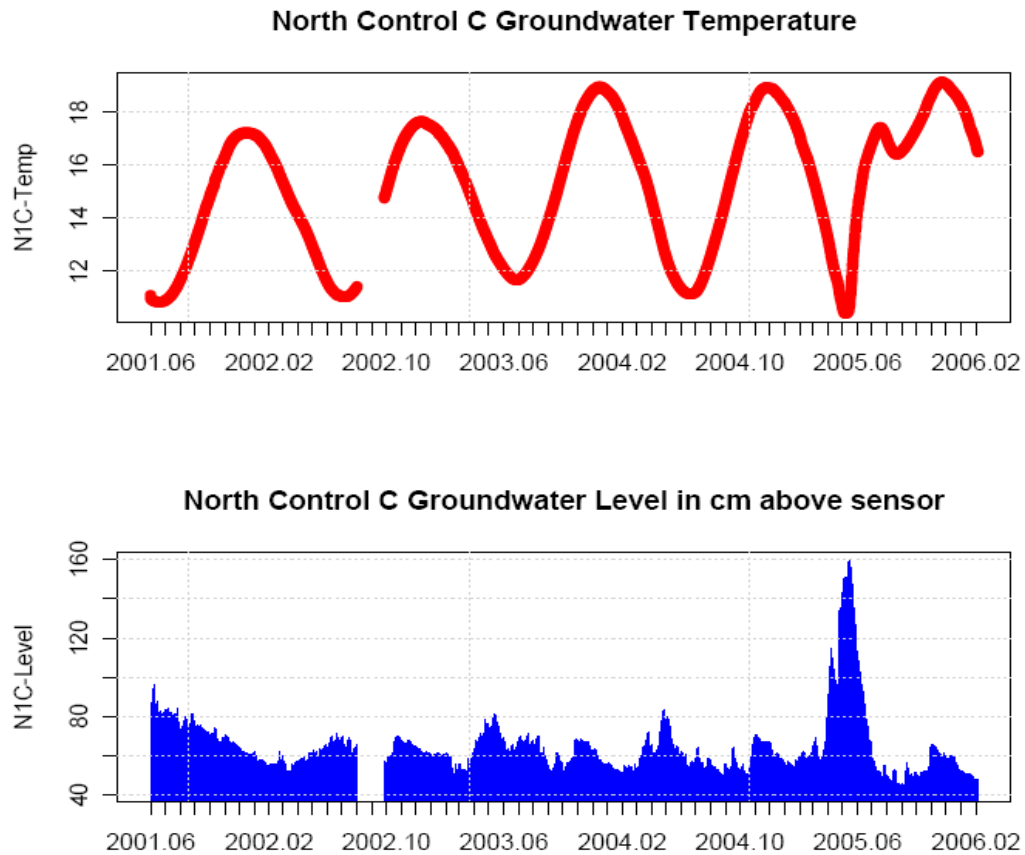


Figure 1. North 1 Well C (N1C) – Control Groundwater Temperatures and Groundwater Levels.

Most notable in the N1C record, aside from seasonal periodicity, is the strong groundwater level spike in early 2005. An aperiodic temperature anomaly clearly coincides with this spike. The other North records showed similar events.

Other variables investigated include annual precipitation data and monthly annual streamflow data. Direct precipitation is an important water source for plants in the Rio Grande Bosque. However, it does not contribute largely to the groundwater levels in areas where it falls (Finch et al. 2002). Figures 2 and 3 summarize the precipitation recorded near the northern and southern limits of the study areas.

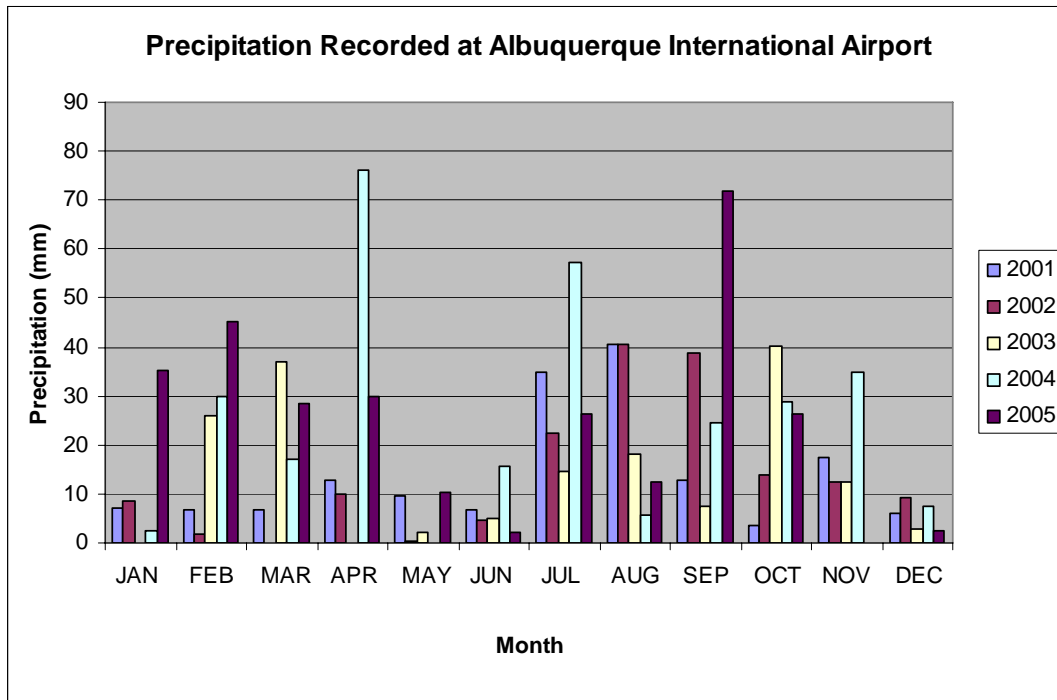


Figure 2. Precipitation Recorded at Albuquerque International Airport (Western Regional Climate Center 2006).

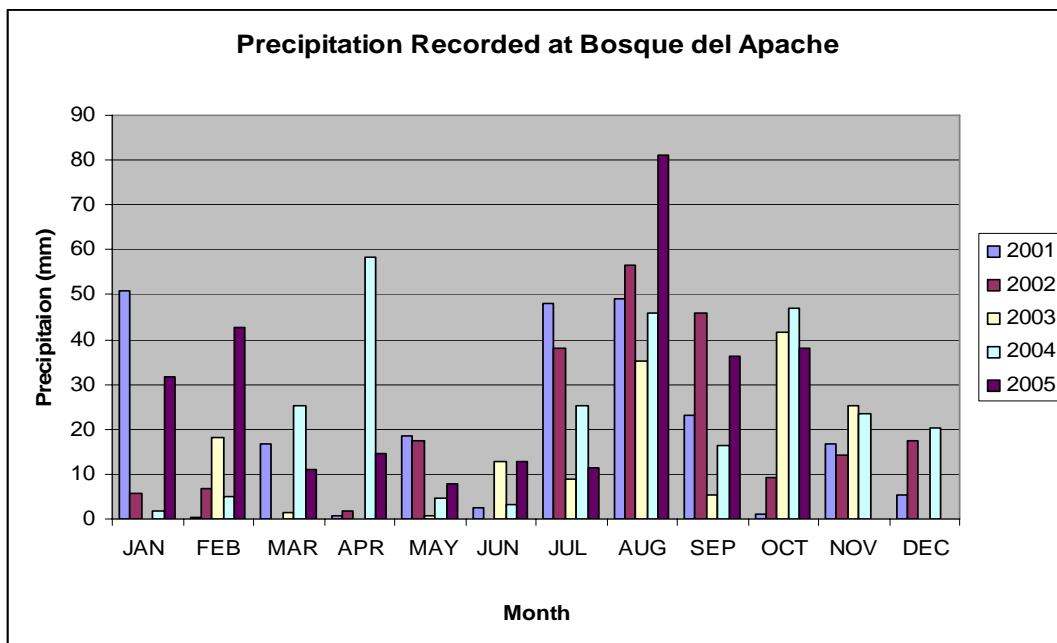


Figure 3. Precipitation Recorded at Bosque del Apache (Western Regional Climate Center 2006).

A primary source of groundwater in the Bosque is water that percolates into the ground from the river and canals that pass through the Bosque (Finch et al. 2004). Figure 4 illustrates monthly average streamflow measured from a USGS gage on the Rio Grande near Albuquerque.

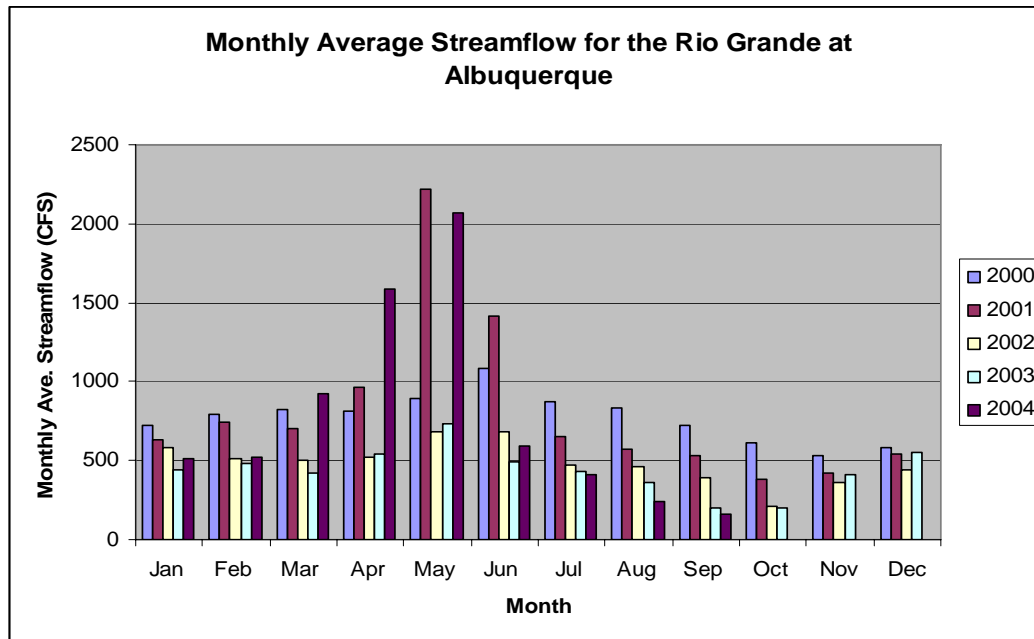


Figure 4. Rio Grande streamflow measured USGS gage 08330000 (U.S. Geological Survey 2006).

Precipitation and river discharge source files are obtained or converted into, from their respective sources, as time-stamped CSV files, and can be aligned with the time-stamped well CSV files for further visualization and analysis using R.

Future Work to be Performed

As we continue to make progress with the hydrological portion of the Fuels Reduction Study (FRS), we have determined the following points to be part of future work that will assist in a more complete understanding of how groundwater levels are potentially affected by the three treatments performed at each site. These points are by no means exhaustive, but provide a template for future work to be executed:

- Survey wellhead elevations and, if feasible, link to local benchmarks to establish wellhead height above mean sea level (msl)
- Complete merging of data into time-stamped CSV files, one per well
- Validation of data, including identification of outliers and gaps
- Work with the RMRS statistician to conduct robust statistical analysis, including inter-site and inter-block ANOVA of groundwater temperatures and levels
- Investigate correlation of groundwater levels with Rio Grande discharge and regional precipitation rates

- Link treatment location, type, and timeline to hydrological data using time-stamped CSV files
- Link other FRS time-series data such as ground surface temperature and relative humidity to hydrological data using time-stamped CSV files
- Link other FRS spatial data such as soil profiles and topology to hydrological data using ArcGIS
- Continuation of preparation of an annual report as required of the Joint Venture Agreement with the University of New Mexico WRP, and the RMRS

By investigating correlations among treatment type, groundwater levels and temperatures, and regional spatial and hydrological data, we hope to reveal the influence of the various treatment types on local processes such as evapotranspiration rates, stream-groundwater coupling, and infiltration of precipitation in the Middle Rio Grande Bosque. If a complete analysis reveals substantial changes in groundwater rates at the study sites, then recommendations for future Bosque land and water management could be made at the appropriate time. The results of this study could be applicable to similar southwestern United States regional riparian area studies to develop sound research strategies to mitigate the long-term reversal of current trends of riparian ecosystem degradation.

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